Electric Energy Education Requirements for Electric Ships

Reforming Electric Energy Systems Curriculum with Emphasis on Sustainability
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How are Ship Power Systems Different?

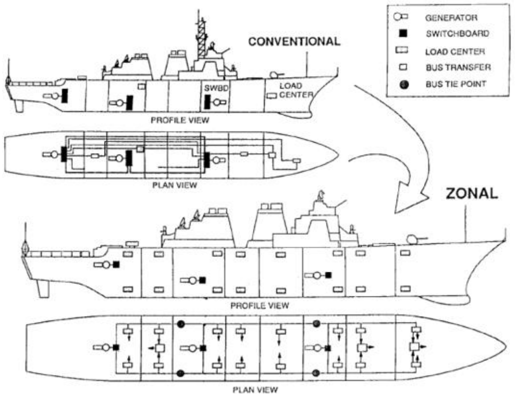
- Variable Frequency:
  - Limited rotational inertia of the prime movers and generators
  - Frequency fluctuations can be expected to last up to 2 seconds (or longer)
- Lack of Time Scale Separation
  - Principal time constants of controls, machine dynamics, and electric dynamics all fall within the same general range of milliseconds to seconds.
  - Decomposing by time scale separation is much more difficult.
- Load Sharing instead of Power Scheduling:
  - Real and reactive power are shared equally among all paralleled generators through the very fast exchange of load sharing information.
  - Strong coupling of the dynamics of all the paralleled generators.
- Short Electrical Distances:
  - Transmission line modeling not needed unless considering pulse loads.
  - Tighter dynamic coupling of the various electrical power system elements.
- Load Dynamics:
  - Must account for dynamics of propulsion motors, large pumps, pulsed loads, propeller dynamics, and ship dynamics.
- Tighter Control:
  - A higher level of centralized control can be exercised.
- Ungrounded or high-impedance grounded systems:
  - Enable continued operation with a single line to ground fault.
- Physical Environment:
  - Able to operate in a pitching, and rolling ship.
  - Must account for vibration, humidity, salinity, and shock.

Undergraduate Focus

- Electrical Engineering Fundamentals
- Rotating Machines
- Feedback Control
- Power Electronics
- Thermal Systems / Heat Transfer
- Modeling and Simulation
- Standards and Specifications
- Test and Evaluation
- Design for Production
- Reliability, Maintainability, and Availability

Design and Production of Power System Elements

Graduate Focus

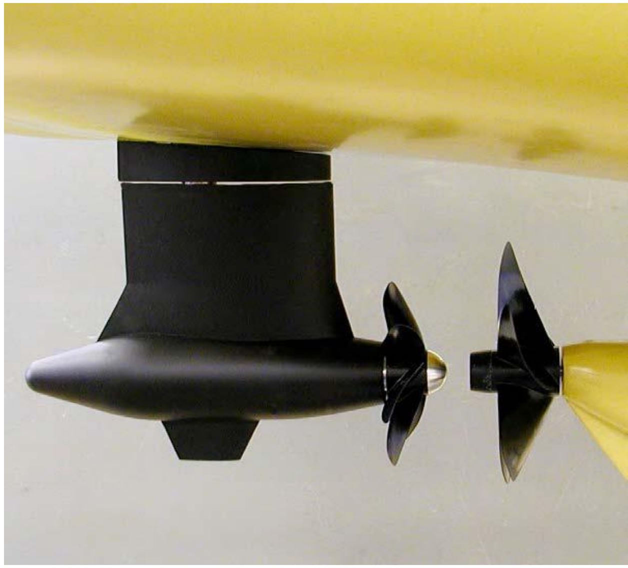


- Power System Design
- Power System Components
- Distributed Control Systems
- Fault Detection, Localization, and Isolation
- Grounding Systems
- System Stability – small signal and large signal
- System Modeling and Simulation
- Shafting, Bearings, Thrust Bearings, and Propellers (traction systems)
- Gas Turbines, Diesel Engines, and Fuel Cells (Photovoltaic – Wind – Geothermal)
- Thermal Systems
- Design for Shipboard Environment (other vehicles, mines, extreme locations)
- Writing Specifications and Standards – Interface-ology
- Load Estimation (Stochastic and Load Factors)
- System Reliability, Maintainability, and Availability
- System Survivability (susceptibility, vulnerability, recoverability)
- Design Management Techniques

Lead Shipboard Power System Design Team

Other Thoughts

- Multi-disciplinary team design projects are good.
- Multi-disciplinary team studies are good too.
  - Develop insight rather than design.
  - Learn Set-Based Design / Design Space Exploration.
    - Design the requirements
    - Translate requirements into a Specification
  - Conduct Cost Benefit Analysis.
    - Net Present Value
    - Real Options Theory
    - Understand Risk



" Guide for Conducting Technical Studies " SNAME T&R 7-10, 8/6/2014
http://www.sname.org/communities1/resources/viewtechnicalpaper/?DocumentKey=c01ac9f4-7ad0-43b1-bee3-ef015b5b3454